Imaging Radar Applications in the Death Valley Region

Tom G. Farr
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA
tom.farr@jpl.nasa.gov

Death Valley has had a long history as a testbed for remote sensing techniques (Gillespie, this conference). Along with visible-near infrared and thermal IR sensors, imaging radars have flown and orbited over the valley since the 1970's, yielding new insights into the geologic applications of that technology. More recently, radar interferometry has been used to derive digital topographic maps of the area, supplementing the USGS 7.5' digital quadrangles currently available for nearly the entire area.

As for their shorter-wavelength brethren, imaging radars were tested early in their civilian history in Death Valley because it has a variety of surface types in a small area without the confounding effects of vegetation. In one of the classic references of these early radar studies, Schaber et al. (1976) explained in a semi-quantitative way the response of an imaging radar to surface roughness near the radar wavelength, which typically ranges from about 1 cm to 1 m. This laid the groundwork for applications of airborne and spaceborne radars to geologic problems in arid regions. Radar's main advantages over other sensors stems from its active nature- supplying its own illumination makes it independent of solar illumination and it can also control the imaging geometry more accurately. Finally, its long wavelength allows it to peer through clouds, eliminating some of the problems of optical sensors, especially in perennially cloudy and polar areas.

Imaging radars are almost always monostatic, meaning they use the same antenna for illumination and reception. Thus, image tone, which is proportional to the amount of energy arriving back at the antenna after scattering off the ground, is related to how diffuse the scattering is. A smooth surface (at the scale of the wavelength), such as a still body of water or a paved parking lot, will reflect the energy like a mirror, sending it away from the receiving antenna, yielding a dark image tone. As a surface becomes rougher, say from sand to gravel to cobbles to boulders, more and more energy is scattered in random directions, rather than in the specular direction, so more energy makes it back to the receiver and the area appears in lighter tones. Thus imaging radars produce images of the physical nature of the surface, complementary to the compositional information produced by optical sensors. A secondary characteristic of the surface, its dielectric constant, which is proportional to moisture content plays a much smaller part, but can sometimes be seen to affect image tone around springs and after rainfall.

The earliest imaging radars to be flown over Death Valley included military tests of short-wavelength (3 cm) X-band sensors (Schaber et al., 1976). Later, the Jet Propulsion Laboratory began its development of imaging radars with an airborne sensor, followed by the Seasat orbital radar in 1978. These systems were L-band (25 cm). Seasat was designed for oceanographic work, but it was quickly realized that its data were highly useful for geologic studies. Its early failure probably helped bring more attention to its land applications, as well. Following Seasat, JPL embarked upon a series of Space Shuttle Imaging Radars: SIR-A (1981), SIR-B (1984), and SIR-C (1994). The most recent in the series was the most capable radar sensor flown in space and acquired large numbers of data swaths in a variety of test areas around the world. Death Valley was one of those test areas, and was covered very well.

At the same time, the aircraft radar program continued improving and collecting data over Death Valley, including tests of a relatively new technique called imaging radar interferometry. This adds a second antenna analogous to stereo imaging, allowing digital topographic maps to be generated. In September, 1999 SIR-C will ride again as the Shuttle Radar Topography Mission, with the addition of a second antenna at the end of a 60 m mast with the goal to collect data for a global 30 m resolution digital topographic map.

Other countries have not been idle during this time. The European Space Agency has operated a pair of radar satellites, ERS-1 and 2 for a number of years, while Japan has flown JERS-1 and Canada has Radarsat-1.

Geologists have used radar images for a long time as surrogates for airphotos in areas of perennial cloud cover. Structures, even though covered with a vegetation canopy, show up surprisingly well not because the radar is penetrating through the canopy, but because the small illumination-angle variations caused by the canopy following the underlying topography are highlighted more in radar images than in optical images. In arid regions, it has been recognized that the weathering habit of a rock outcrop will determine its appearance in a radar image. Resistant, jointed rocks tend to appear bright, while fissile easily comminuted rock types appear dark. These characteristics may be helpful in sorting out ambiguities in optical remote sensing data.

Another useful application for imaging radar is mapping of surficial deposits and processes. Many surficial geomorphic processes act to change the roughness of a surface. In Death Valley, the most common processes are salt weathering (in the lower elevations), aeolian deposition, and desert pavement formation. Daily et al. (1979) found that combining Landsat optical images with airborne radar images were useful for mapping several alluvial fan units, based on desert varnish formation in the optical wavelengths and desert pavement formation in the radar images. Taking this further afield, Farr and Chadwick (1996) applied a similar approach to map fan units in a high valley in western China. These results make a case for the possibility that different surficial processes leave diagnostic signatures in multi-sensor remote sensing data, a possibility that will require much more extensive tests for uniqueness in different environments. A more quantitative attempt at connecting radar images with surficial processes was undertaken by Farr (1992). Building on the work of Dohrenwend et al. (1984) and Wells et al. (1985), roughness changes with age at Cima Volcanic Field were quantified using close-range stereo photography from a helicopter. The results were then compared with radar images inverted to become maps of surface roughness (Evans et al., 1992).

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